Improvements to the CAMx Photochemical Model for Winter Ozone

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Air Quality in Utah: Science for Solutions II

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RAMBOLL ENVIRON

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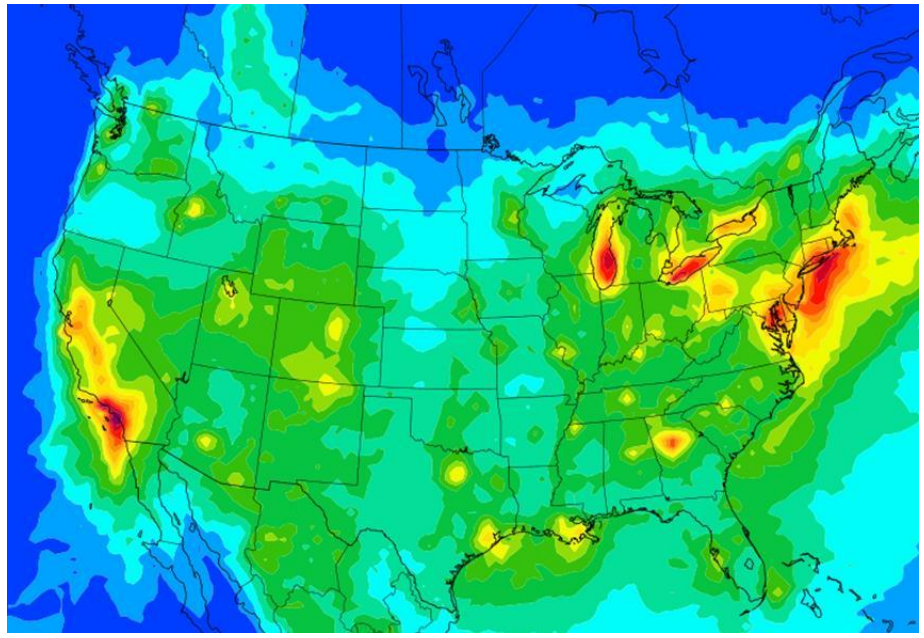
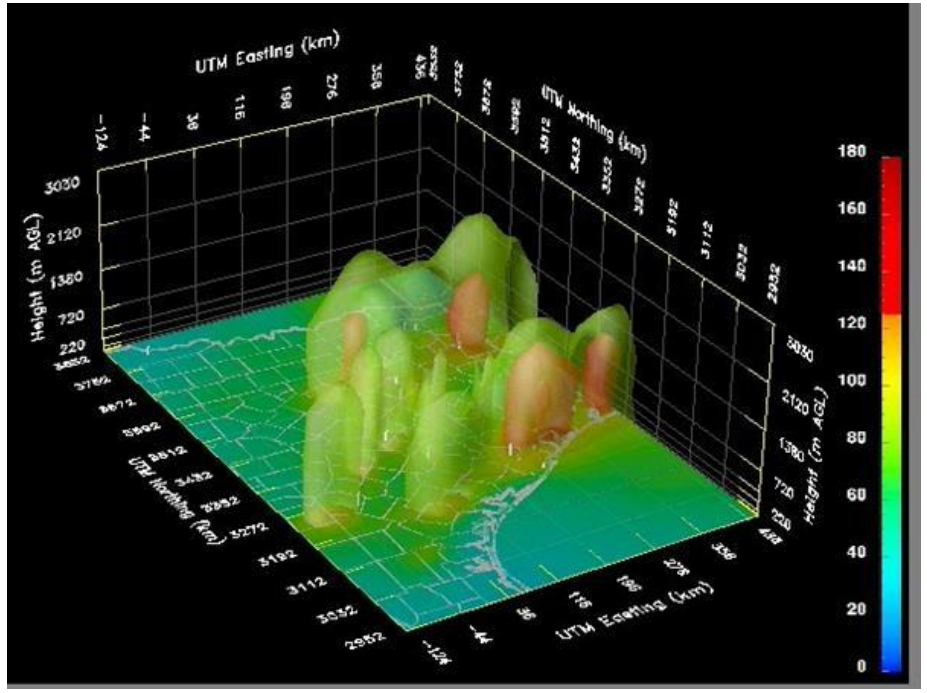
WHAT IS CAMx?

- A three-dimensional photochemical grid model
  - It's like a weather prediction model, BUT:
  - It simulates the movement and chemical evolution of pollutants through the atmosphere
- Such models help us:
  - Explain observed conditions
  - Understand complex processes
  - Identify source culpability
  - Investigate mitigation strategies
- CAMx needs many types of "big" data
  - Emissions, meteorology, surface characteristics, etc.





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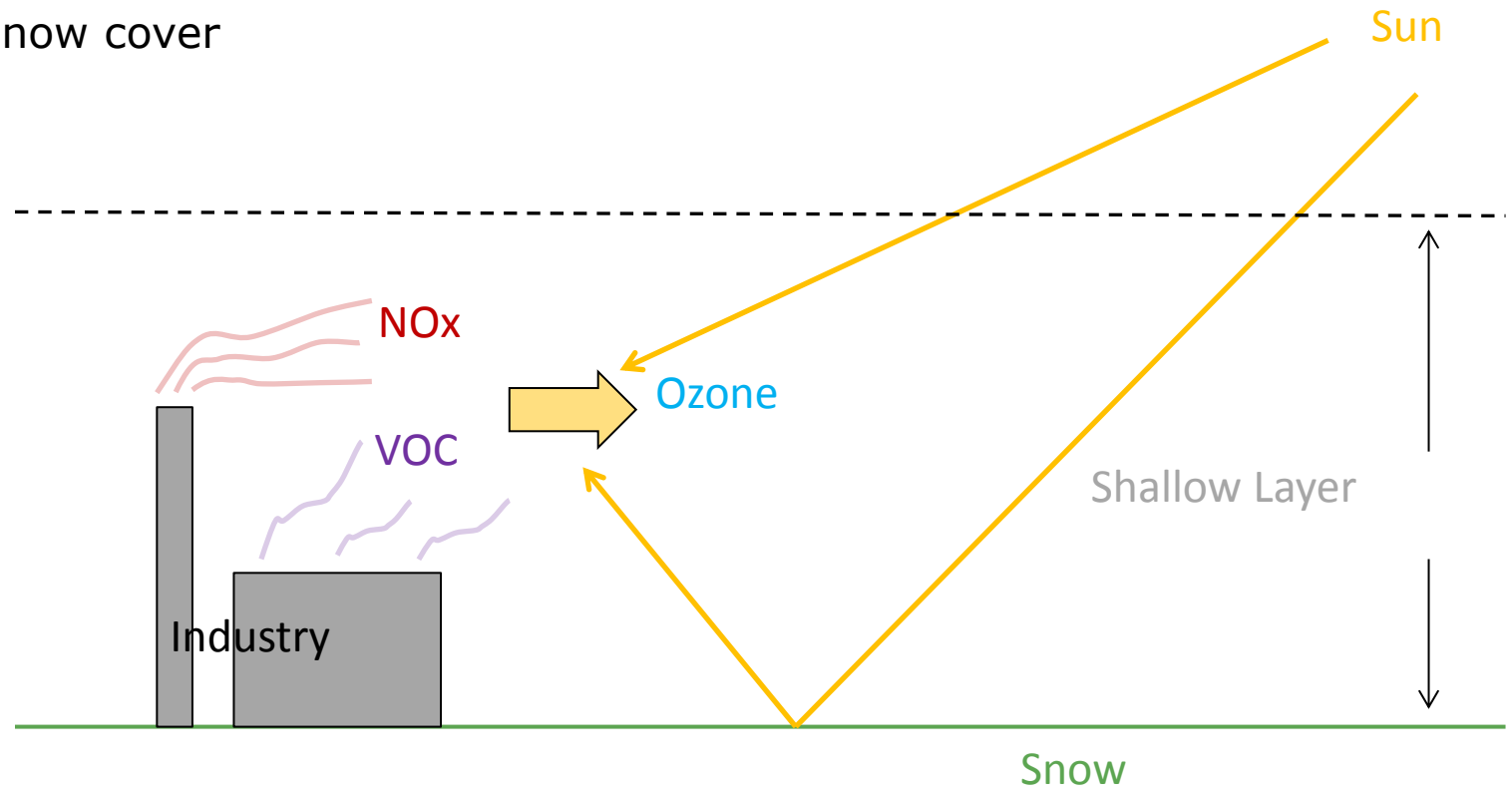
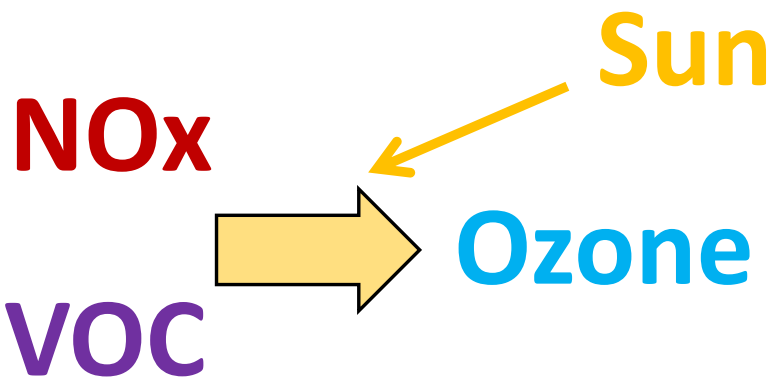
PROJECT PURPOSE

- This project looks to improve on two pieces of the difficult wintertime ozone modeling puzzle
  1) Atmospheric chemistry for western Oil & Gas basin conditions
  2) Treatment of snow cover

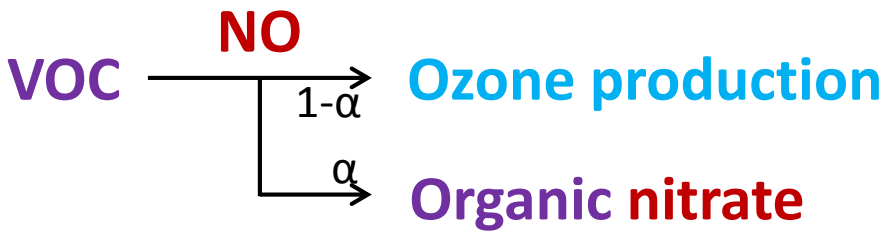


ARE CHEMISTRY CHANGES NEEDED FOR WINTER OZONE?

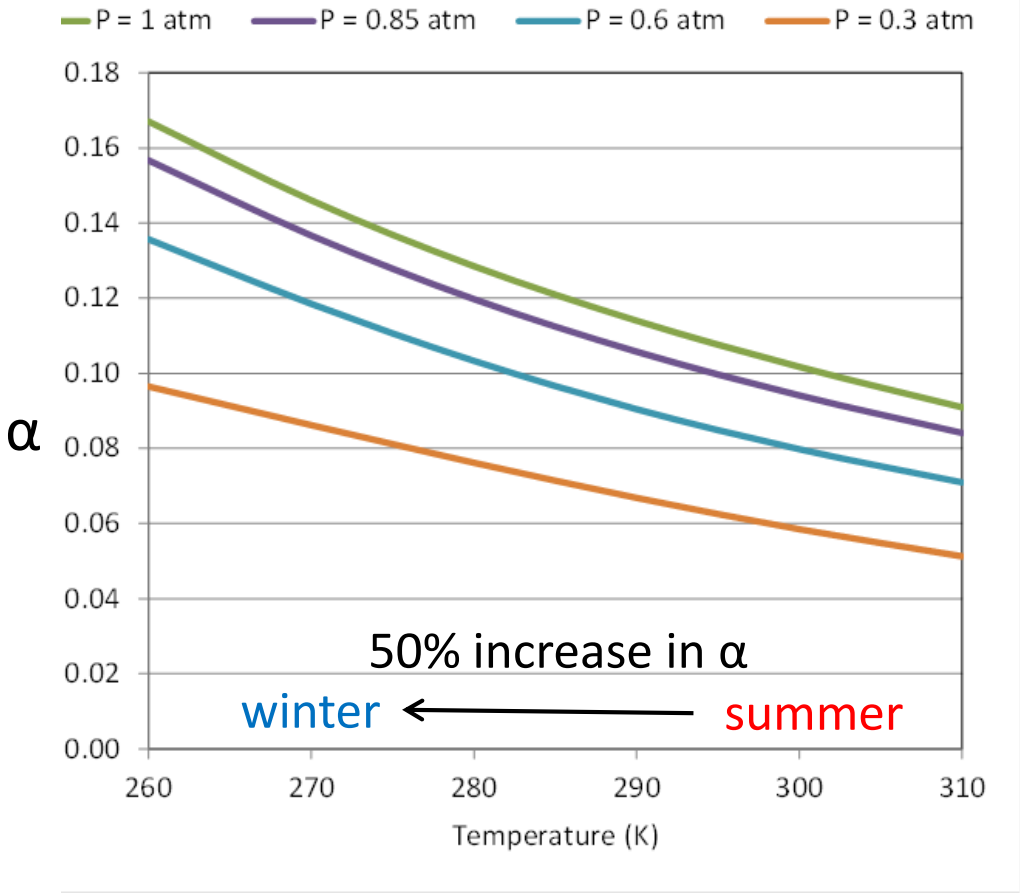
- Photolytic effect of sunlight
  - Little variation with temperature
- Chemistry of NOx and similar molecules
  - Cold conditions are understood
  - NOx chemistry is important for ozone from surface through stratosphere
- Chemistry of VOC
  - Models developed for summer ozone
  - There is potential for improvement
  - Focus on the most abundant VOCs in western US O&G basins: Alkanes



ALKANE CHEMISTRY



- Fraction (α) of organic nitrate formed depends on temperature and pressure (altitude)
  - But models hold α constant
  - Including this dependency should improve winter chemistry modeling
  - Important for O&G basin conditions
- Dynamic branching ratio added to CB6(r3)



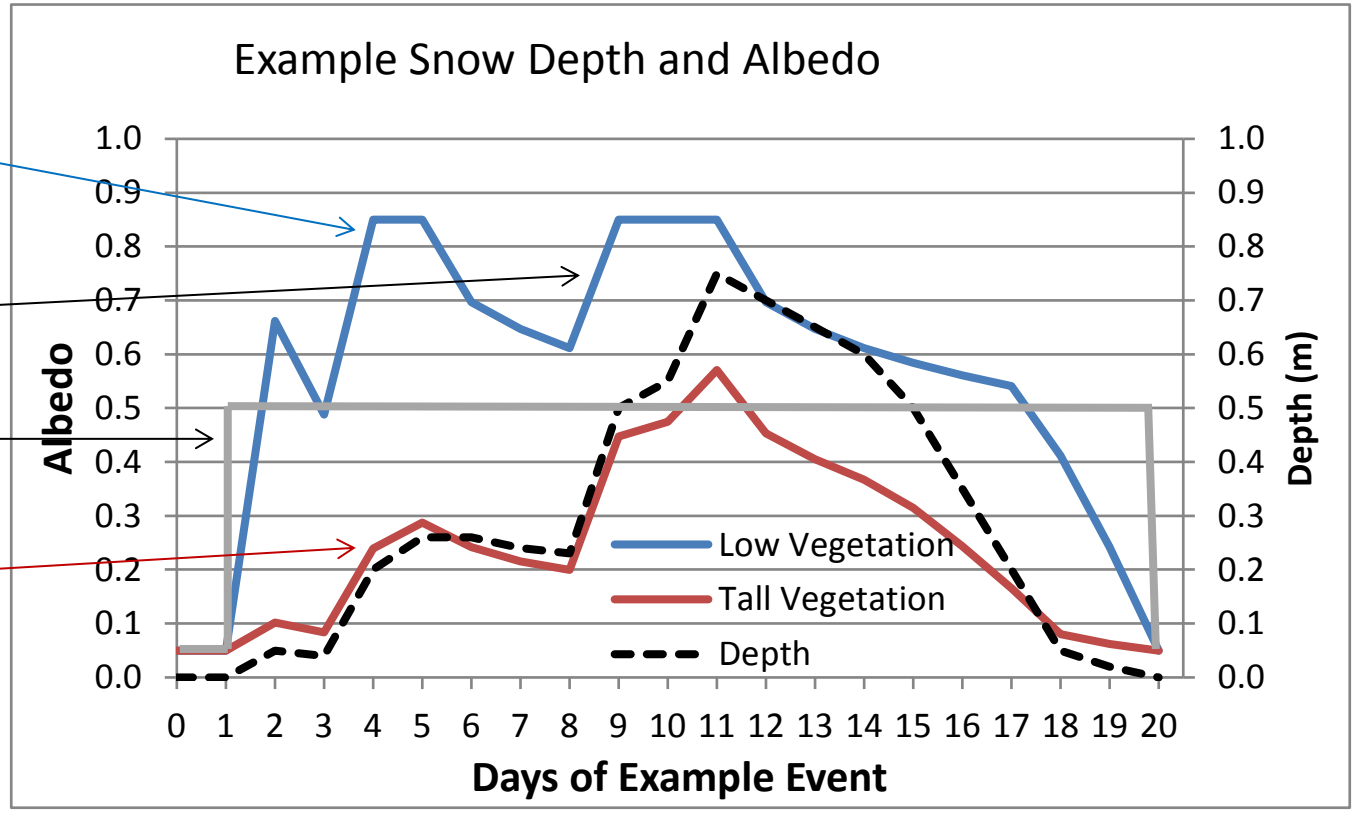
IMPROVEMENTS FOR SNOW ALBEDO

Low vegetation covered faster/completely, maximizing snow albedo

New snowfall increases snow depth and "freshens" the albedo

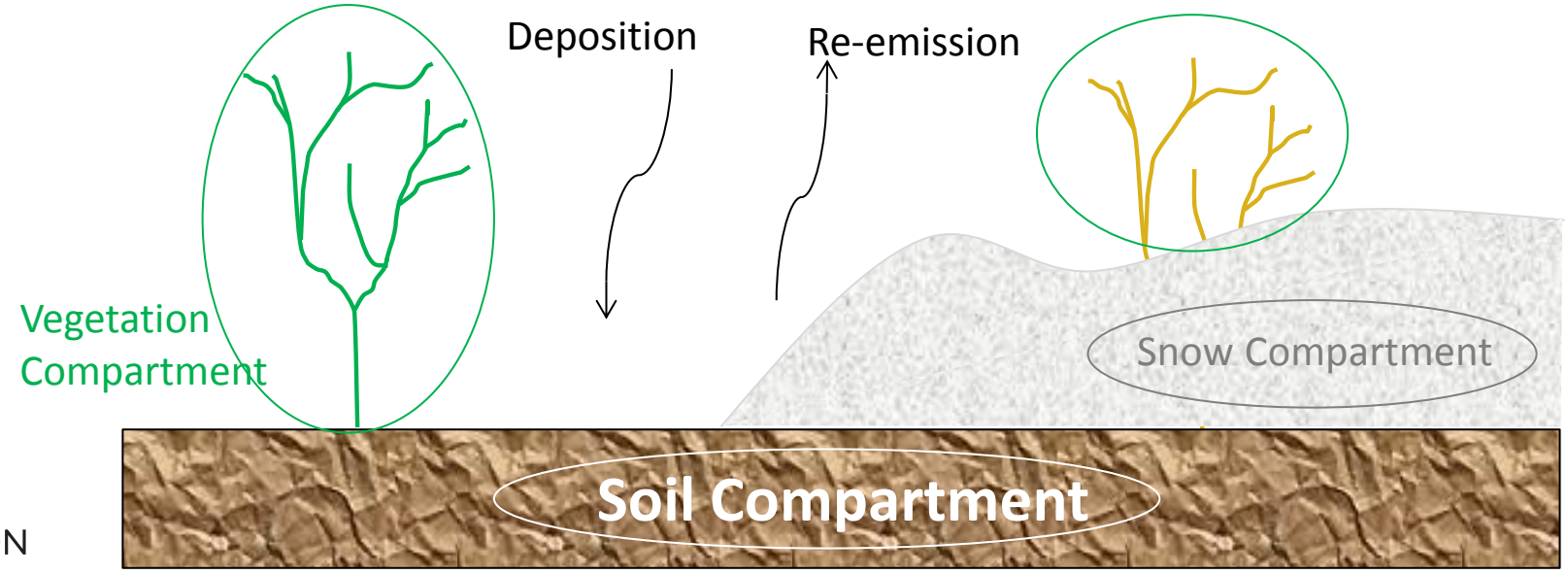
Original albedo assumption

Tall vegetation covered slower/incompletely, minimizing snow albedo



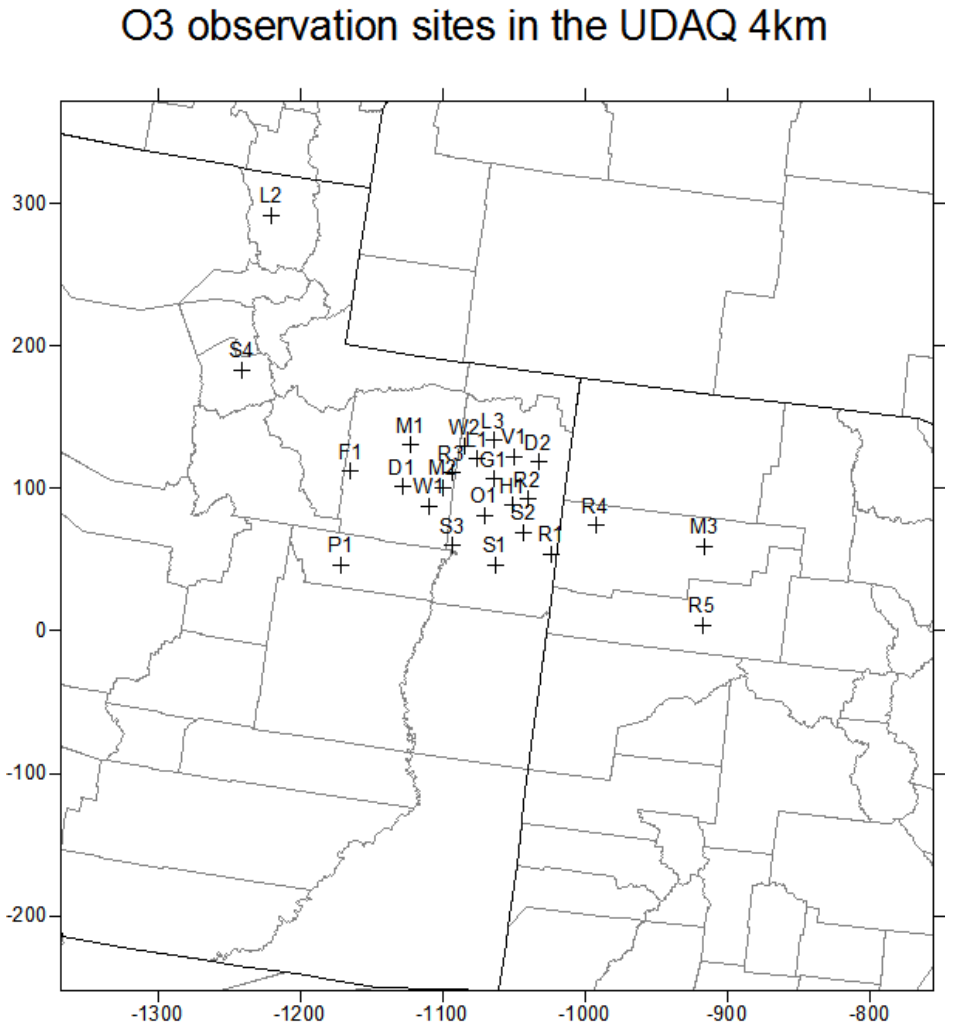
SURFACE CHEMISTRY UPDATE

- Optional model component:
  - Two-way transfer between atmosphere and surface system
  - Chemical interactions among deposited material form products that re-emit
- Updated to include snow with soil and vegetation compartments
- Do models need to account for snow surface-atmosphere chemistry interaction?
  - May be an important contributor to atmospheric chemistry



EVALUATION IN UINTA BASIN

- Model:
  - CAMx v6.1 with snow/chemistry updates
- Domain:
  - UDAQ 4-km grid over eastern Utah
  - February 1-7, 2013 (during UBOS)
- Datasets:
  - UofU-derived meteorology
  - (Initial) Older UDAQ-derived emissions
  - (Latest) NEIv2/UDAQ-derived emissions
  - Boundary conditions from a global model
  - NOAA/UBOS 2013 measurements



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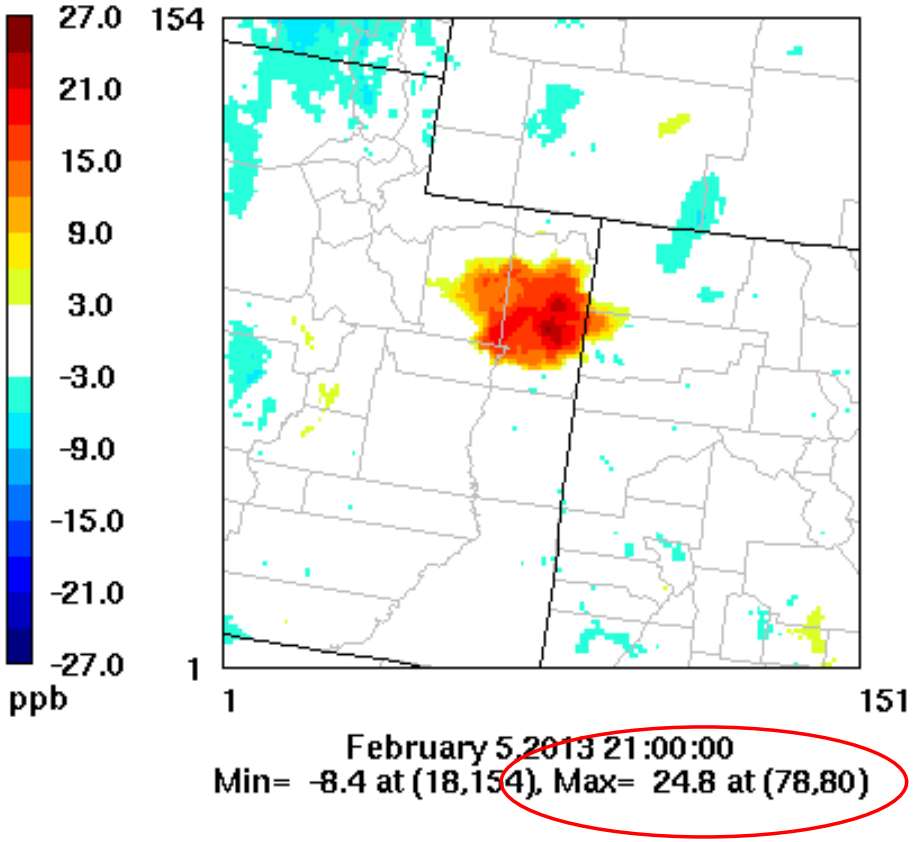
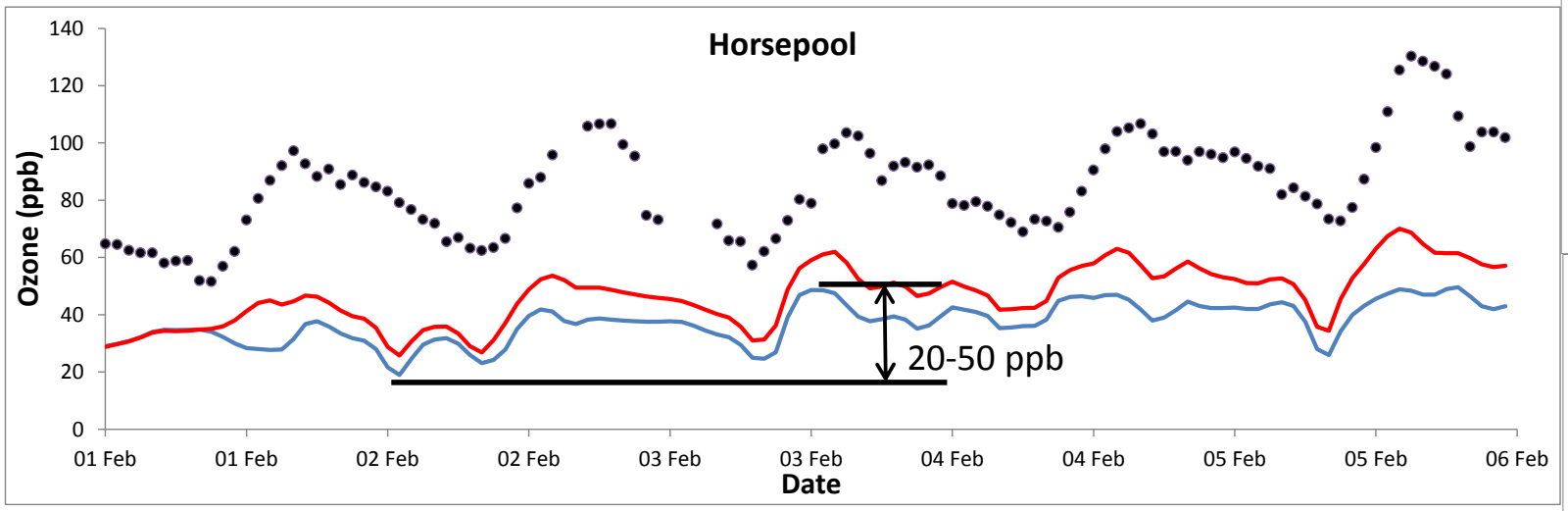
INITIAL OZONE SIMULATIONS

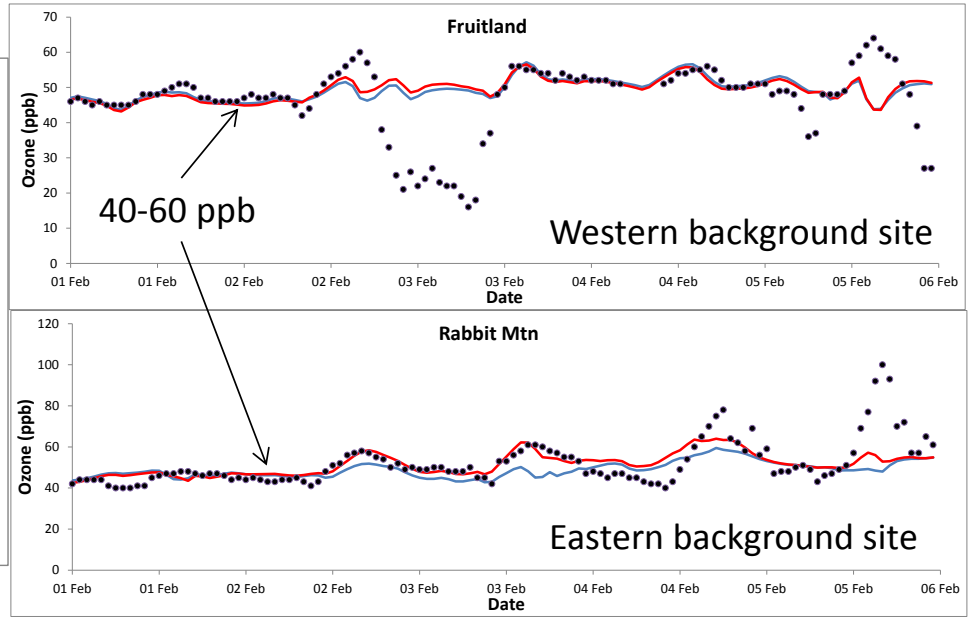
- Total effect of all model updates:
  - 10-20 ppb O_3 **increase**
- Snow albedo/deposition update:
  - O_3 **increase**
- Winter chemistry update:
  - O_3 **decrease**
- Surface chemistry update re-emitting HONO:
  - O_3 **increase**
  - Surface chemistry configured for ***testing purposes only***!
  - Highly speculative, currently no conclusive evidence for a surface chemical pathway

Effect with New Snow + Chemistry Update + Surface Model w/ Snow



INITIAL OZONE SIMULATIONS





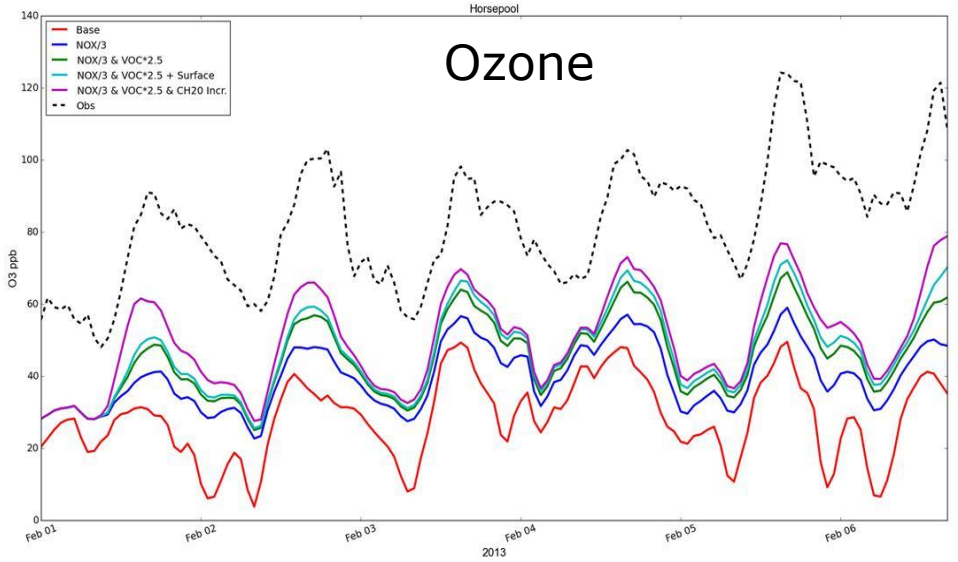
Original Model

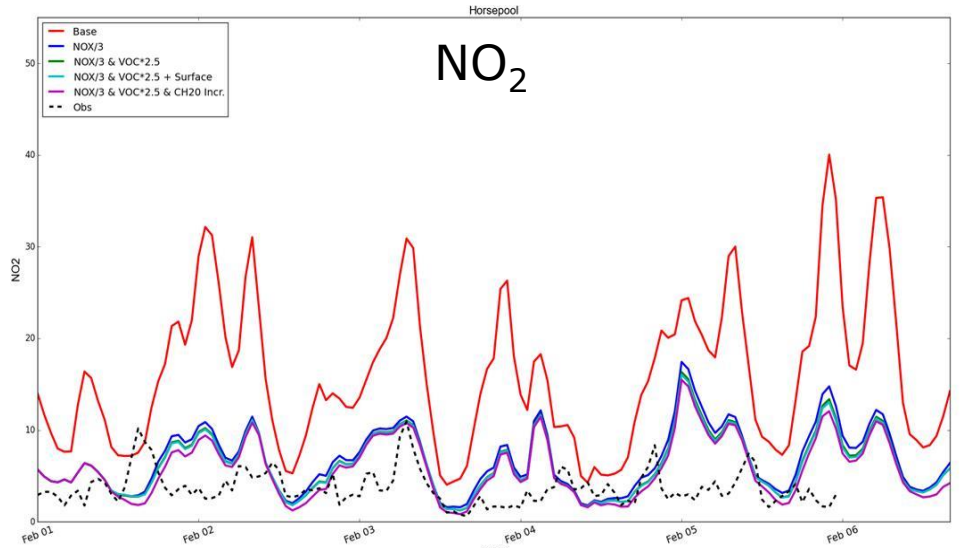
New snow + Chemistry Update + Surface Model w/ Snow

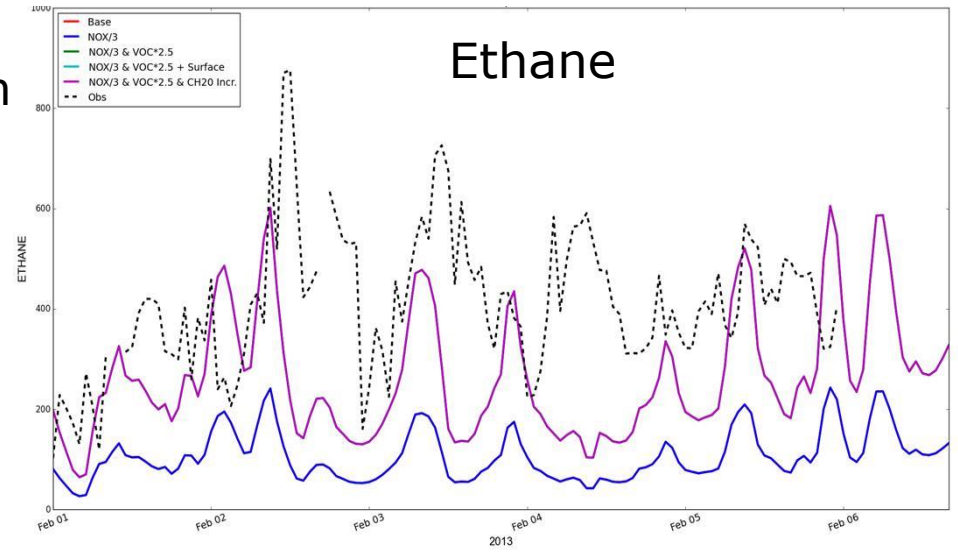
- O_3 is too low in the basin
  - O_3 is inhibited and suppressed
  - Comparisons to 2013 UBOS measurements confirm model is NOx-rich, VOC-poor
- But background is higher and better simulated outside the basin

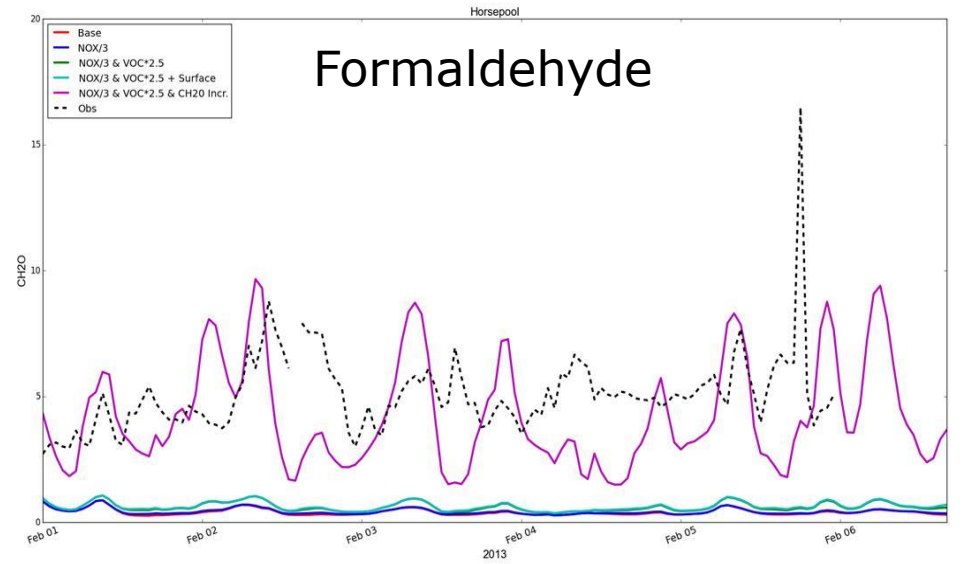
LATEST OZONE SIMULATIONS

- Base (CB6r3+snow)
- NOx/3
- NOx/3+VOC×2.5
- NOx/3+VOCx2.5+ Surface Model
- NOx/3+VOC×2.5+ Formaldehyde
- Still not getting enough ozone
- Ratios of N compounds are wrong – implies missing reactivity









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SUMMARY

- CAMx improvements lead to positive effects, in line with expectations
  - Air chemistry: cold temperatures push NOx out of ozone cycle, reduces ozone slightly
  - Snow: higher albedo, reductions in deposition increase ozone
  - Surface/snow chemistry:
    - May be a source of emissions that increase reactivity and ozone production
    - Complex, uncertain, inconclusive – more study needed, but CAMx now has this capability
  - These updates are insufficient to simulate ozone at measured levels
- Need additional work on emission estimates
  - NOx oxidation products are not correctly replicated: emission-chemistry cycle is not right
  - Too much NOx: over estimated inventory or improper vertical distribution?
  - Too little VOC: under estimating fugitive emissions?
  - Too little formaldehyde: missing a source, ubiquitous use of methanol?

THANK YOU
QUESTIONS?